UNITED KINGDOM QUALITY ASH ASSOCIATION

Technical Datasheet

Fly Ash in Pavement Construction

Pavement thickness design using FABM 1 & 5

(Recommendations are given in good faith and are presented for consideration and adoption by the responsible engineer concerned)

Introduction

Fly ash bound mixtures (FABM) describe mixtures where fly ash is the main component of the binder and where the water content is compatible with compaction by rolling. The term fly ash refers to coal fly ash, often called PFA (pulverized fuel ash) in the UK. The fly ash for FABM can be moistened (known as conditioned) or dry run-of-station ash.

Although fly ash is the main component of the binder it is a pozzolana and needs quick or hydrated lime in order to develop strength. Cement can substitute for lime but is not as effective in mobilising the full pozzolanic and thus cementing potential of the fly ash (Table 1).

Table 1: Compressive strength in MPa of treated fly ash

Age of 1:1 sealed cylindrical specimens cured @ 20C	*Fly ash with 2.5% CaO*	*Fly ash with 5% CaO*	*Fly ash with 7% CEM 1*	*Fly ash with 9% CEM 1*
7 days	1.5	2	3	5
28 days	4	4	4	8
91 days	5	7.5	6	9

FABM based on cement behave like cement bound mixtures (CBM), thus quick setting and hardening with little laying flexibility during construction. FABM based on lime however are, slow-setting, slow-hardening, self-healing (autogenous-healing) mixtures, which have the advantage of the laying flexibility of unbound-materials during construction but the performance of CBM in the medium to long term. Both FABM and CBM belong to that family of pavement materials known as hydraulically-bound mixtures (HBM).

FABM are standardized in BS EN 14227-3 as follows:

- FABM 1: 0/31.5 mm graded mixture
- FABM 2: 0/20 mm well-graded mixture with a compacity (air voids) requirement. 0/14 & 0/10 mm mixtures are also available
- FABM 3: sand mixture
- FABM 4: mixture with a producer-declared grading
- FABM 5: fly ash (as aggregate) treated with lime or cement.

FABM use aggregates in accordance with BS EN 13242 and fly ash in accordance with BS EN 14227-4.

Regarding application, Highways Agency (HA) design recommendations for FABM are found in HD 26. These focus on the use of FABM 1 as the base material but are theoretically based and unproven. The design recommendations described in this datasheet are those based on the actual use and proven performance of FABM in Staffordshire and Kent since 1997.

Design recommendations for new roads, maintenance and strengthening

The designs presented here take account of developments with pavement terminology and concepts introduced by the HA in 2006. Primarily however, the designs draw on existing and proven UK experience with FABM, and data from the documents listed in the Bibliography.

Design recommendations are given in Tables 2 & 3. These tables have been formulated to satisfy both new build and maintenance scenarios. All that is required to use the tables is knowledge of the design traffic in millions of standard axles (msa) and the support condition of the supporting layer/formation. The tables **must** be read in conjunction with the 'notes and construction advice' that accompany the tables.

Table 2 gives recommendations for 'FABM 1 base on FABM 1 sub-base' and continues the successful design practice in Staffordshire and Kent used since 1997. However the recommendations now also cater for different construction scenarios for the sub-base including:

- overlaying both before and after setting,
- the degree of trafficking and whether directly trafficked.

The advice is based in part on recommendations in LR1132, Figure C3: Thickness of granular sub-base for different levels of construction traffic but applied to FABM 1 before setting when it behaves as an unbound granular material.

Table 3 gives similar recommendations for FABM 1 base but this time on FABM 5 sub-base and it is particularly relevant where aggregate for FABM 1 may be in short supply but fly ash is readily available. Table 3 has been developed from continental experience (France) and sub-base advice in LR1132, HD25/94 and IAN 73.

Table 2: Road pavement design using FABM 1 base on FABM 1 sub-base

Traffic (msa)	***Thickness of asphalt (mm). ****	***FABM 1 base thickness (mm) for T2** strength category***	***FABM 1 (T2** strength category) sub-base thickness (mm) as a function of the equilibrium CBR of the sub grade or formation and the construction scenario***.*** ***Note no capping is required. However, where capping in accordance with Table 4 is used, the CBR 15% column shall apply***							
			CBR 15%	CBR 10%	CBR 7%	CBR 5%	CBR 4%	CBR 3%	CBR 2.5%	CBR 2%
30-50	130	180	150	180 (150)	200 (150)	230 (170)	260 (200)	300 (230)	350 (260)	400 (300)
12-30	100	180								
2-12	100	150								
< 2	80	150								

* combined surface course (TSC, HRA, surface dressing) & asphalt concrete binder course. The combined thickness can be reduced to not less than 100mm subject to a corresponding equal increase in thickness of the FABM 1 base.

** T2 R_tE class is required where R_tE denotes the couple of tensile strength and elastic stiffness - equivalent to compressive strength classes C5/6 & C6/8.

*** The figures in parenthesis in the table denote the thickness where either;

- the FABM sub-base is overlain the same day or next day (i.e. before setting – set normally occurs after 2/3 days) and is not subject to direct trafficking other than by the plant for the placement of successive FABM lifts or layers,
- or where the sub-base lift/layer has set and will not be subject to direct trafficking of any sorts i.e. overlying FABM must be laid over itself.
- For all other scenarios, the thicker recommendations shall be employed.

Table 3: Road pavement design using FABM 1 base on FABM 5 sub-base

Traffic (msa)	*Thickness of asphalt (mm). **	*FABM 1 base thickness (mm) for T2** strength category*	*FABM 5 (T2** strength category) sub-base thickness (mm) as a function of the equilibrium CBR of the sub grade or formation and the construction scenario***. Note no capping is required. However, where capping in accordance with Table 2 is used, the CBR 15% column shall apply*							
			CBR 15%	CBR 10%	CBR 7%	CBR 5%	CBR 4%	CBR 3%	CBR 2.5%	CBR 2%
30-50	130	200	170	200 (170)	240 (200)	280 (230)	330 (270)	400 (300)	470 (350)	530 (400)
12-30	100	200								
2-12	100	180								
< 2	80	180								

* combined surface course (TSC, HRA, surface dressing) & asphalt concrete binder course. The combined thickness can be reduced to not less than 100mm subject to a corresponding equal increase in thickness of the FABM 1 base.

** T2 R_tE class is required where R_tE denotes the couple of tensile strength and elastic stiffness equivalent to compressive strength classes C5/6 & C6/8.

*** The figures in parenthesis in the table denote the thickness for scenarios where either;

- the FABM sub-base is overlain the same day or next day (i.e. before setting – set normally occurs after 2/3 days) and is not subject to direct trafficking other than by the plant for the placement of successive FABM lifts or layers,
- or where the sub-base lift/layer has set and will not be subject to direct trafficking of any sorts i.e. overlying FABM must be laid over itself.
- For all other scenarios, the thicker recommendations shall be employed.

Other notes and construction advice for Tables 2 & 3

1. FABM 1 & 5 shall be specified in accordance with the series 800 of the HA's Specification for Highway Works (SHW).
2. In the case of frost susceptible sub-grade material or capping, the depth of overlying non-frost susceptible construction shall satisfy local requirements. FABM to T2 strength category can be considered resistant to frost heave.
3. With the possible exception of reconstruction work where deep excavation may not be desirable, designs incorporating 'sub-base on capping' foundations, rather than thick sub-base directly on sub grade, are preferred for subgrades with design CBR<5%. Capping material should be to the 600 series of the SHW and thickness should be in accordance with Table 4 and should be used in conjunction with the sub-base thickness for the column titled 'CBR 15%' in tables 2 and 3.

Table 4: Capping thickness (where appropriate)

Sub grade design CBR (%)	*< 1.5*	*1.5*	*2*	*2.5*	*3*	*4*	*5-8*	*9-14*	*15*
Depth of unbound or stabilised capping with a soaked CBR of 15% to SHW clauses 613, 614 or 615 (mm)	Sub-grade replacement	600	500	400	350	300	250	200	150

4. Sub-bases are best constructed on well-drained and properly constructed and compacted formations. Particular attention should be paid to the uppermost 1m of fills, cut/fill zones and 'at-grade' areas.
5. It is suggested that clay sub-grade/sub-formation should be categorized for design as no higher than CBR 3%. Anything higher than 3% requires thorough attention to drainage and earthworks both during construction and in-service.
6. FABM 1 base layers should be laid in one lift.
7. Subject to satisfactory density compliance, individual lifts of FABM 1 or 5 sub-base should not be thinner than 150mm or greater than 230mm.
8. To avoid damage to weak formations, the first lift of multi-lift FABM should be as thick as possible compatible with above.
9. Not more than 3 days should elapse between sub-base and base or successive lifts of FABM but, ideally and preferably, both should be laid the same day or the second lift not more than 1 day later and before drying out or contamination of the underlying lift or layer.

10. Ideally, FABM is best laid in the period May to September inclusive, particularly if to be left exposed without overlying layer protection, but in any event, whatever the time of year, it is advisable that FABM be overlain as soon as possible to limit exposure to weather and traffic or protected with a surface dressing.
11. Where drainage and edge details are to be constructed on stabilized formations prior to sub-base placement, the use of binder combinations employing cement is recommended. The construction of drainage and edge details from or on FABM 5 is also not recommended. These should be founded on the formation.

Bibliography

- 1977 Catalogue des structures types de chaussees neuves. DR, SETRA, LCPC, France .
- 1998 Catalogue des structures types de chaussees neuves. DR, SETRA, LCPC, France.
- WILLIAMS R I T 'Cement-treated pavements' (Elsevier Applied Science, 1986).
- LR 1132. The structural design of bituminous pavements. TRL 1984.
- TRL 611. A guide to the use and specification of cold recycled materials for the maintenance of road pavements. TRL. 2004.
- TRL 615. Development of a more versatile approach to flexible and flexible composite pavement design. TRL. 2004.
- HD26. Pavement Design. DMRB Volume 7 Part 3. HIGHWAYS AGENCY
- HD25. (Pavement) Foundations. DMRB Volume 7 Part 2. HIGHWAYS AGENCY [issued as IAN 73/06 in 2006].
- BS EN 14227-3. Hydraulically bound mixtures – Specifications – Part 3: Fly ash bound mixtures. BSi, London, UK.
- BS EN 14227-4. Hydraulically bound mixtures – Specifications – Part 4: Fly ash for hydraulically bound mixtures. BSi, London, UK.
- BS EN 14227-14. Hydraulically bound mixtures – Specifications – Part 14: Soil treated by fly ash. BSI, London, UK. BS EN 13242. Aggregates for unbound and hydraulically bound materials for use in Civil engineering work and road construction. BSi, London, UK.
- Specification for Highway Works. 800 Series. MCHW Volume 1
- UKQAA data sheets;
  - 6.0 Fly ash in pavement construction – Overview of FABM & SFA
  - 6.1.1 Fly ash in pavement construction – FABM 1 (fly ash bound granular material)
  - 6.1.2 Fly ash in pavement construction – FABM 5 (treated fly ash)
  - 6.1.3 Fly ash in pavement construction – SFA (soil treated with fly ash)
  - 6.2 Fly ash in pavement construction – Laboratory mixture design for FABM & SFA
  - 6.3 Fly ash in pavement construction – Thickness design using FABM 1 & FABM 5
  - 6.4.1 Fly ash in pavement construction – Specification for FABM 1
  - 6.4.2 Fly ash in pavement construction – Specification for FABM 5
  - 6.4.3 Fly ash in pavement construction – Specification for SFA
  - 6.5 Fly ash in pavement construction – Fly ash & lime stabilised clays – preventing sulfate heave

In general usage the term 'fly ash' is used for pulverized coal ash but it can also cover ash from burning other materials. Such 'fly ash' may have significantly differing properties and might not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to PFA / fly ash produced from the burning of predominantly coal in power stations.

Version 5.1 May 2011